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FINAL REPORT

FOR

DEPARTMENT OF ENERGY CONTRACT

DE-FG03-91SF-18864

APPLICATION OF A HIGH-DENSITY GAS LASER TARGET TO THE PHYSICS OF X-RAY LASERS AND CORONAL PLASMAS

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ABSTRACT

An experiment had been proposed to investigate a photopumped x-ray laser approach using a novel, high-density, laser heated supersonic gas jet plasma to prepare the lasant plasma. The scheme to be investigated uses the He-like sodium 1.10027 nm line to pump the He-like neon 1s-4p transition at 1.10003 nm with the lasing transitions between the n=4 to n=2,3 states and the n=3 to n=2 state at 5.8 nm, 23.0 nm, and 8.2 nm, respectively. The experiment had been proposed in 1990 and funding began in January 1991. After extensive preparations to perform the experiment on the GDL laser, a series of circumstances made it impossible to pursue the research over the past 5 years. These were 1) lack of access to the GDL laser and its eventual closing, 2) the inability to identify an alternate laser system with which to perform the experiment, and 3) the lack of problem relevancy after 5 years of delays. As a consequence, it has been decided not to pursue the research any further.

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Section 1

INTRODUCTION

The objective of this project was to conduct an experimental investigation of a photopumped x-ray laser approach using a novel, high-density, laser-heated supersonic gas jet plasma to prepare the lasant plasma. The scheme to be investigated uses the He-like sodium 1.10027 nm line to pump the He-like neon 1s-4p transition at 1.10003 nm with the lasing transitions between the n=4 to n=2,3 states and the n=3 to n=2 state at 5.8 nm, 23.0 nm, and 8.2 nm, respectively. The intent was to use the Glass Development Laser (GDL) to separately characterize both the neon lasant plasma and the sodium pump plasma to determine the experimental parameters necessary to attempt the more complicated undertaking of a two-plasma experiment looking for fluorescence and gain using a higher-power laser system such as OMEGA.

The first goal was to line-focus the GDL, using 1054 nm light, into a sheet of neon gas and create a plasma. The planar flow would be produced from a custom-designed MACH 4 nozzle having a 1-D DeLaval cross-section. The exit aperture of the nozzle is 1 mm wide and 10 mm long and is affixed to a valve using a magneto-restrictive material as the operating mechanism. The experiments would determine the incident laser power density needed to maximize the fraction of Ne IX in the plasma without over heating to the H-like Ne X charge state. The dimensions of the plasma would be measured by x-ray imagery and average neon plasma temperatures would be determined using line ratios.

The second objective was to experimentally characterize the sodium pump source. It is necessary to measure the absolute power in the Na X pump line in order to determine the feasibility of observing gain, or at least fluorescence, in an actual two-plasma experiment. The first is desired to determine the irradiation conditions necessary to maximize the intensity of the sodium pump line. Second, the relative timing between the maximum sodium pump line emission and the attainment of the maximum Ne IX abundance must also be measured in order to perform an actual two-plasma photopumping experiment.

Data acquired in this study would be used to determine the feasibility of a two-plasma photopumping experiment using the laser irradiation conditions available at the NLUF. If the the results should indicate that sufficient Na IX pump line power can be generated by laser irradiation, the data would be used to perform a detailed experimental design for implementation at the NLUF.

The experiments would also assess the suitability of high-density gas jet laser targets to simulate the long scale length coronal plasma which surrounds directly-driven laser fusion targets. These laser-fusion targets are expected to have coronal plasma scale lengths on the order of a millimeter or so which is the same as the generated by the gas jet target to be used in the experiment. Such a relatively low density long scale-length plasma could be used to study parametric decay instabilities which can cause laser beam filimintation and hot spots. Stimulated Raman and Brillouin scattering in the coronal region of the fusion plasma can severely effect the performance of laser-fusion targets. By using this plasma source it should be able to conveniently create coronal plasmas at well defined atomic densities suitable for ICF-related studies and should be considered an important subsidiary objective.

The high-density gas-jet target used in this experiment has been developed under a Lockheed Martin Advanced Technology Center (ATC) internally funded independent x-ray laser research program. The objective of this program is to explore the viability of using a laser heated gas jet target to generate a relatively uniform plasma column suitable as an x-ray laser medium. Lockheed Martin has worked closely with the Plasma Research Corporation Inc. [1] to design and fabricate the nozzles and high-pressure valves which compose the gas jet target system. One potential advantage of such a gas target is that it should be possible to make a planar, laminar, gas flow which should be initially quite uniform and which has density gradients much less severe than those found in laser-produced plasmas from solid targets.

The proposed experiments were to have been performed on DOE's Glass Development Laser (GDL) at the Laboratory for Laser Energetics (LLE), University of Rochester, which operates at a wavelength of 1054 nm. From the standpoint of coupling the laser radiation to the jet it is desired to use the longest pulse available, preferably on the order of 1-ns. The beam was to be line focussed to a 1-cm length or as close to this length as possible so that the entire 1-cm long sheet of gas was illuminated. The line-focus was to be at a point approximately 2-mm above the nozzle exit orifice where atomic densities as high as 10^{19} atoms/cm^3 could be achieved which implies electron densities of a few times 10^{20} cm^{-3}.

Section 2

EXPERIMENTAL APPROACH

The contract for this investigation commenced on 15 January 1991 with P. C. Filbert as Principal Investigator. Preparations were made for the experiment to be performed on the GDL laser. Diagnostic equipment (such as x-ray diode arrays and spectrometers were prepared and calibrated) and the gas jet was optimized for use on this facility. After extensive preparations had been made, the experimenters were later informed that the availability of the laser would be delayed due to the lack of funding for the upgrade and operation of the GDL facility. Eventually, the facility became permanently unavailable and was closed. Sometime after this period of delays, P. C. Filbert left the company and was no longer available to act as Principal Investigator. The co-principal investigators, J. G. Pronko and D. Kohler, assumed the responsibility for the contract. Only 55% of the original funding remained after all of the early preparations prior to and during the past 5 years of delays.

It became apparent that it was necessary to find an alternate facility on which to perform the experiment. The Lockheed Martin Advanced Technology Center in Palo Alto, Ca is conveniently located near Lawrence Livermore National Laboratory (LLNL). Since the commute time is approximately 45 to 60 minutes between the two facilities and a close relationship has been maintained in the past with the laser groups at LLNL, it was decided to investigate the possibility of forming a collaborative effort with one of the groups for this experiment. Carrying out the research at LLNL has the additional advantage of having no expensive travel expenses associated with the experiment and technical delays would not have as great an impact on the program resources.

Discussions were held with groups at the Lawrence Livermore National Laboratory (LLNL). Unlike the collaborative effort that was arranged for a second NLUF contract [2] that Lockheed Martin had with the DOE, no common interest could be found to pursue this research at LLNL. This was due to the fact that the characteristics of the available lasers did not suit the experimental needs and the problem was no longer relevant because of research performed by other groups in the intervening 5 years.

Section 3

SUMMARY

The experiment had been proposed in 1990 and funding began in January 1991. A series of circumstances has made it impossible to pursue the research over the past 5 years. These were 1) lack of access to the GDL laser and its eventual closing, 2) the inability to identify an alternate laser system with which to perform the experiment, and 3) the lack of problem relevancy after 5 years of delays. As a consequence, it has been decided not to pursue the research any further. All remaining project funds will be returned to the DOE.

REFERENCES

1. Plasma Research Corporation Inc., 5675 Chappell Place, Oakland, CA 94619.

2. Final report for DOE contract DE-FG03-92-SF19200 submitted on March 31, 1996 by Lockheed Martin Missles and Space Company (LMSC-F254282)